
JOSEPHINE COUNTY WATER MANAGEMENT
IMPROVEMENT STUDY, OREGON

SAVAGE RAPIDS DAM

SEDIMENT EVALUATION STUDY

Savage Rapids Dam is located in southwestern Oregon, on the Rogue River, just 5 miles upstream from the town of Grants Pass (figure 1). Savage Rapids Dam was built in 1921 to divert riverflows for irrigation. The dam is 39 feet high and creates a backwater pool that extends $\frac{1}{2}$ mile upstream during the nonirrigation season and 2- $\frac{1}{2}$ miles upstream during the irrigation season (figure 2). The reservoir is relatively narrow, only two to three times wider than the river. The annual mean flow of the Rogue River is 3,372 cubic feet per second (ft³/s). The total drainage area is 2,459 square miles. The mean annual runoff is 19 inches, the highest recorded peak flow was 152,000 ft³/s on December 23, 1962, and the lowest mean-daily flow recorded was 744 ft³/s. Although the dam has fish ladders, these ladders are old, do not meet current fisheries criteria, and allow only limited fish passage. Dam removal has been proposed to restore fish passage to natural conditions. The dam would be replaced with two pumping plants that would deliver water to the irrigation canals. Grants Pass Irrigation District (GPID) requested a sediment study to model the potential sediment-related impacts of dam removal.

Sediment is defined as unconsolidated solid material that comes from weathering of rock and is carried by, suspended in, or deposited by water or wind. Sediment is often classified by its particle size: clay (less than 0.005 millimeter [mm]), silt (0.005 to 0.075 mm), sand (0.075 to 4.75 mm), gravel (4.75 to 75 mm), cobble (75 to 300 mm), and boulder (greater than 300 mm). All natural rivers transport a certain amount of sediment. The amount of sediment transported depends on the amount of sediment supplied from the upstream watershed and on the velocity and turbulence of the flowing river. Fine-grained sediments, such as clay and silt, are typically transported by the river while suspended in the water (figure 3) and do not compose a significant portion of the river bed ("wash load"). A river's capacity to transport wash load is typically much greater than the amount supplied. Riverbed sediments typically consist of coarse-grained particles such as sand, gravel, and cobble. Sand-sized particles can be transported by a river in suspension, if river velocities and turbulence are great enough, or rolled and bounced along the river bed as "bedload." Gravel and coarser-sized sediment particles are typically transported by a river as bedload.

Study Purpose

The purpose of this study was to determine the potential sedimentation impacts resulting from removing Savage Rapids Dam. Among the many significant concerns with this project are the volume, particle size gradation, and spatial distribution of

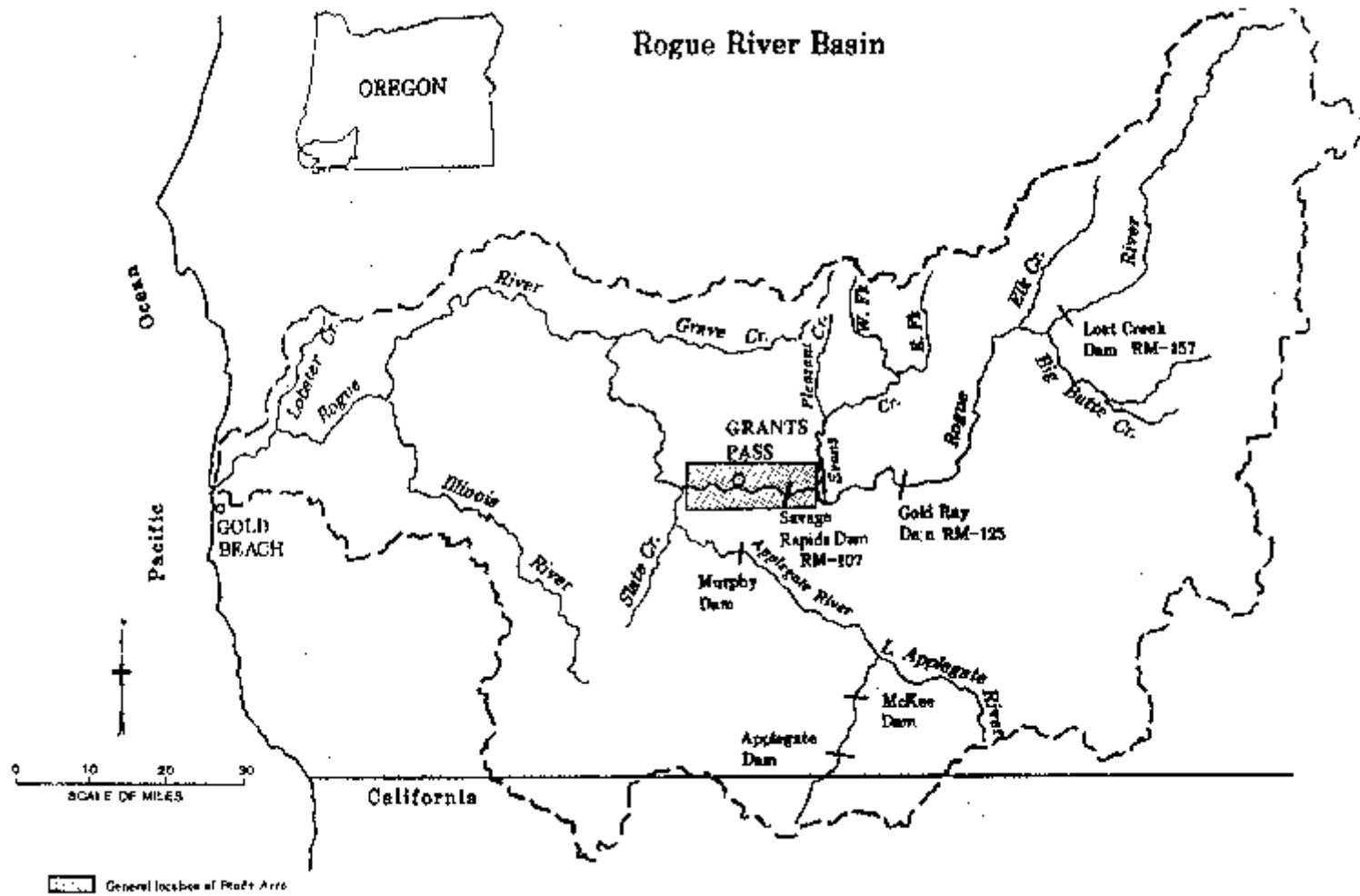


Figure 1.—Study area location map.



Figure 2.—View of Savage Rapids Dam, located on the Rogue River in southwestern Oregon, 5 miles upstream from Grants Pass. Photograph by Tim Randle on February 23, 1999. The mean-daily flow on this date was 7,400 ft³/s (U.S. Geological Survey gauge at Grants Pass, Oregon).

sediment accumulated within the reservoir (see Appendix A), the chemical composition of the reservoir sediment (see Appendix C), and the rate at which the reservoir sediment would be eroded if the dam is removed (see Appendix B). Further, this study discusses the expected rate at which the eroded reservoir sediment would be transported down-stream, and the location and magnitude of deposition that might result downstream from the dam. Specific areas of interest include the potential for sediment deposition at the proposed GPID pumping plants and at the water intake and treatment operations for the City of Grants Pass.

Authority for the Study

Authority to conduct this investigation is provided in Public Law (P.L.) 92-199, enacted December 15, 1971 (85 Stat. 664), which authorizes the Bureau of Reclamation (Reclamation) to conduct a feasibility study of the Grants Pass Division, Rogue River Basin Project.

Events Leading to Study Initiation

Prior to 1971, Reclamation's involvement with Savage Rapids Dam and the GPID was limited to congressionally authorized emergency repairs and various modifications to the dam in 1953-54 and in 1957-58. In December 1971, the Congress passed P.L. 92-199,

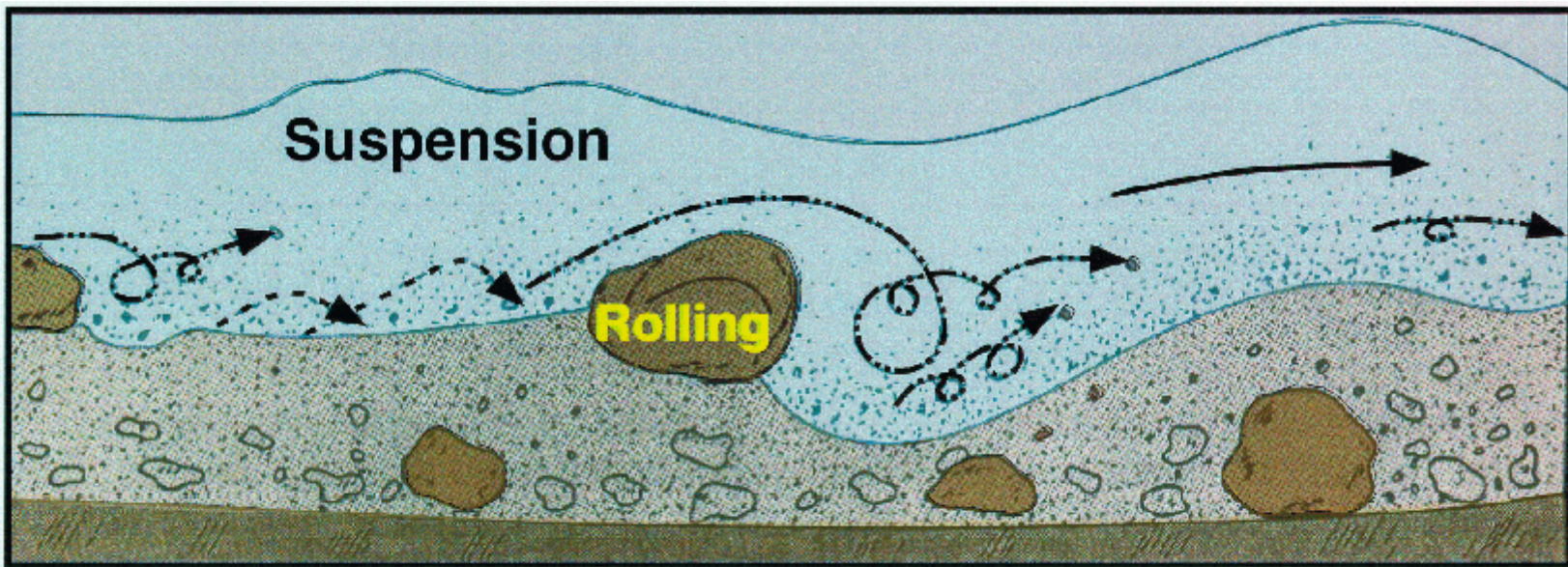


Figure 3.—Coarse sediment (sand and gravel) are transported as bedload along the river channel bottom.
Fine sediment (silt and clay) are transported in suspension.

which authorizes the Secretary of the Interior to conduct a feasibility study of the Grants Pass Division, Rogue River Basin Project, Oregon. The initial study included fish passage at Savage Rapids Dam and the need to improve the existing GPID distribution system. The two studies were done concurrently.

Reclamation undertook the fish passage study. Because of the immediate need to improve fish passage, the intent was to develop an interim solution to fish passage. All water-related problems and integration of solutions with a permanent solution to fish passage would be considered in a later phase. The results of the fish passage study were published in a special report in 1974. The Congress authorized the measures proposed in the report and appropriated funds for construction in P.L. 93-493. Reclamation completed the *Final Environmental Statement, Anadromous Fish Passage Improvements, Savage Rapids Dam, Rogue River Basin Project, Grants Pass Division-Oregon (INT-FES 76-26)* and made it available to the public on May 18, 1976.

Not all the interim measures identified in the report were implemented. Some work was done on the south fish ladder, but a solicitation for bids to replace the north fish ladder received only one response, which exceeded available funds. In November 1979, it was decided to use the remaining funds to replace the north side fish screens and defer further work on the fish ladders until a permanent resolution of the fish passage issue could be achieved.

A plan formulation working document (Reclamation, 1979) provided some information on the second phase of the study. Following public review, it was concluded that a Federal project to improve irrigation should be deferred. The fisheries part of the study was continued until 1984, when further work was deferred because of uncertainty regarding potential development of hydropower at the dam. It eventually became clear that the State of Oregon would not amend existing legislation to allow hydropower development at the dam. This stopped the Federal Energy Regulatory Commission application and provided impetus to proceed with finding a permanent solution to fish passage problems.

In early March and April of 1987, Josephine County, GPID, and the City of Grants Pass solicited the Commissioner of Reclamation and the Oregon congressional delegation to provide funds for Reclamation to reopen investigations authorized by P.L. 92-199. The Congress provided funding in fiscal year 1989 for the current investigation, called the Josephine County Water Management Improvement Study (JCWMIS), which was initiated at that time. The primary objectives of the JCWMIS were to (1) identify a permanent solution to salmon and steelhead passage problems at Savage Rapids Dam and (2) help resolve conflicts over water uses in Josephine County. Reclamation prepared and distributed a progress report on the fishery portion in May 1992 and a report on GPID water management in December 1992.

On January 5, 1994, the GPID Board voted to remove Savage Rapids Dam if certain conditions, including capital and operational funding, water availability guarantees, and

protection from liability exposures, could be met. In March 1994, GPID submitted a water management plan (Newton, 1994) to the Oregon Water Resources Commission. It was anticipated that any water conservation/management alternatives suggested in the report would be privately funded. Accordingly, Reclamation did not prepare a report on water management options for consideration by the Congress.

A planning report/final environmental statement (PR/FES), filed on August 30, 1995, and subsequent record of decision (ROD), signed on March 14, 1997, focused only on salmon and steelhead passage concerns at the dam and the associated diversion facilities. The environmental statement (FES) concluded that fish passage and protective facilities at Savage Rapids Dam were inadequate and caused a significant loss of salmon and steelhead. The FES also included a preferred alternative (Pumping Alternative) that included removal of the existing dam. This alternative provided the greatest net economic benefits consistent with protecting the Rogue River fisheries. Also, it would result in the re-establishment of a free-flowing reach of river while providing new electrically driven irrigation diversion pumping facilities.

With the completion of the PR/FES and ROD, Reclamation considered its study of alternatives to improve salmon and steelhead passage at Savage Rapids Dam and the evaluation of those alternatives under the National Environmental Policy Act to be complete. Reclamation chose not to pursue authorization and funding to implement the PR/FES Preferred Alternative because of a lack of strong local consensus.

After completion of the PR/FES, the Oregon Legislature passed a law directing establishment of a task force to review the findings of the report and to make recommendations. That task force completed its work and recommended a dam retention option. The task force based its recommendation largely on sediment-related concerns which resulted from documented examples of sediment damage to other North American rivers where dams were either demolished or breached by high water. Concerns regarding the accumulated sediment behind Savage Rapids Dam continued to be expressed by the chairman of the task force following release of the task force recommendations. The following sediment-related issues were discussed by the task force.

- (1) The sediment may contain hazardous contaminants from upstream mining and other human activities.
- (2) The sediment might plug pumps or cause elevated maintenance costs for pumps proposed for construction immediately downstream from the dam to supply water to the GPID.
- (3) Release of the sediment could affect fisheries and fish habitat downstream from the dam.

- (4) Release of sediment could affect the municipal water supply system of the City of Grants Pass, which is located 5 miles downstream from the dam.
- (5) Release of the sediment could cause barriers to safe navigation of the Rogue River downstream from the dam.

Sportfish Heritage funded sampling and testing of the sediment behind the dam in 1998, and McLaren/Hart conducted the sampling under contract. McLaren/Hart checked for the presence of toxic metals and volatile organic compounds (VOCs). The Environmental Protection Agency reviewed the McLaren/Hart (Sportfish Heritage) report and concluded that the data contained therein indicated that release of the sediments would present minimal ecological risk from VOCs or heavy metals contamination.

Reclamation originally planned to do a detailed sediment study as part of predesign activities if the Congress approved the removal of the dam and provided adequate funding to do so. However, GPID, the Oregon Water Resources Department, National Marine Fisheries Service, WaterWatch, and others agreed that the sediment study should occur sooner (to accomplish that goal). These entities assisted in acquiring Federal funding for this sediment evaluation study.

Description of the Study Area

Savage Rapids Dam and the GPID service area are within the lower part of the middle Rogue River basin, which includes most of Josephine County and a large part of Jackson County. The middle Rogue is surrounded by mountains, and more than three-fourths of the basin is forest or timberland. The Rogue River is a designated wild and scenic waterway from its junction with the Applegate River, just west of Grants Pass, Oregon, downstream to Lobster Creek Bridge, about 10 miles upstream from the mouth of the river.

Nearly one-half of the total basin area and most of the basin population is contained in the central valley region. Medford, Oregon, the largest city in the region, is located about 30 miles southeast of Grants Pass. Most of the usable land within the valley is well developed and fully utilized within the limits imposed by climatic conditions, soils, topographic features, availability of water, and planning and zoning constraints.

Of the total drainage area upstream from Savage Rapids Dam, 30 percent (686 square miles) is regulated by Lost Creek Reservoir, primarily a flood control reservoir built and maintained by the U.S. Army Corps of Engineers (Corps). A few other reservoirs, such as Emigrant Lake, may also trap a small amount of sediment that would otherwise be delivered to the Rogue River. However, these drainage areas are small relative to that of the Rogue River, and they were not within the scope of this study. Lost Creek Reservoir, which began storage in February 1977, reduces flood peaks at Savage Rapids Dam by storing water during high flood peaks. Lost Creek Dam also traps virtually all of the sediment transported

into the reservoir by the Rogue River during these peak flows. Therefore, virtually no sediment from the uppermost Rogue River drainage gets past Lost Creek Dam.

The Applegate River enters the Rogue River 12.5 miles downstream from Savage Rapids Dam. This tributary contributes large quantities of sediment (sand and gravel) to the Rogue River. Just downstream from the confluence with the Applegate River, the Rogue River enters Hellgate Canyon, a steep, narrow, bedrock canyon that is 65 miles long. The Rogue River exits the canyon approximately 30 miles from the ocean, and the slope of the river flattens out. The Illinois River enters the Rogue River just downstream from the canyon mouth and contributes additional water and sediment to the river.

Description of Savage Rapids Dam and Reservoir

Savage Rapids Dam, built in 1921 to divert riverflows for irrigation, is located at approximate river mile (RM) 107.6 on the Rogue River, at the Jackson and Josephine County line in southwestern Oregon about 5 miles east of (upstream from) Grants Pass, Oregon. The dam is a combination gravity and multiple arch concrete dam with a crest length of 464 feet and a structural height (total height of the dam from the foundation to the top of the crest, including the stop logs) of 39 feet (Reclamation, 1997). The hydraulic height of the dam (height of the structure from the original channel bed elevation to the crest of the dam) is 30 feet. The crest elevation of the dam is 957.6 feet in the 1988 North American Vertical Datum (NAVD) (elevation 953.0 in the 1929 National Geodetic Vertical Datum [NGVD]). The river outlet for the dam consists of two 7- by-16-foot radial gates with a combined capacity of 6,000 ft³/s. Fish ladders are present on both ends of the structure, with the north ladder located on the right abutment of the dam and the south ladder located on the left, adjacent to the headworks for the Gravity Canal.

The permanent pool impounded behind the dam extends about ½ mile upstream from the dam at low flow if the stop logs are removed. Here, a natural formation in the riverbed creates a small riffle. The river flows as a natural stream above the riffle. The spillway crest of the dam contains 16 bays that are numbered sequentially from right to left, beginning at the pumping plant located on the right end of the dam (Russell, 1950). "Stoplogs" are placed in these bays during the irrigation season to enlarge the reservoir pool by raising the hydraulic height 11 feet to elevation 968.6 feet (1988 NAVD) (elevation 964.0 in the 1929 NGVD) for irrigation deliveries. This rise in the reservoir water surface extends the reservoir about another 2 miles upstream to RM 110.6 (near the confluence with Evans Creek) for the duration of the irrigation season that typically extends from about mid-May to about mid-October each year. The stoplogs are removed at the end of the irrigation season, which returns the section of the reservoir upstream from Savage Rapids Park to free-flowing river conditions from the late fall to early spring.

Savage Rapids Reservoir Sedimentation History

When water enters the reservoir behind a dam, flow velocity and turbulence decrease and sediment tends to deposit. The typical water storage volume behind a diversion dam is small, and the pool behind a diversion dam tends to fill with sediment in the first few years of operation. After this initial sediment filling, virtually all sediment transported by the river into the reservoir passes the dam. The reservoir probably filled with sediment to its storage capacity within the first few years of operation, and it is full now.

Nearly all the sediment is naturally transported during periods of high flow on the Rogue River. High flow typically occurs during winter floods and the spring snowmelt runoff when the stop logs are removed. Because the reservoir pool is lowered and extends only ½ mile upstream during these high flow periods, river conditions exist up-stream from the public boat ramp at Savage Rapids Park (see figure 10 in Appendix B). These river conditions cause high velocities relative to the reservoir velocities behind the dam (but no higher than downstream from the dam). High velocities mean the dam does not cause sediment deposition in the upper 2 miles of the reservoir (from the public boat ramp to Evans Creek) during this period. It is possible that a small amount of sediment gets deposited in the upstream end of the reservoir during the irrigation season. However, this sediment would be transported toward the dam during the nonirrigation season, when the reservoir is drawn down. Reclamation's drill crew confirmed the overall pattern of sedimentation when it collected field samples of the reservoir sediment, and divers visually confirmed, by observing the bottom, that the dam does not cause sediment to be permanently deposited in the upper 2 miles of the reservoir.

A riffle existed at the dam site before dam construction. (See figure 11 in Appendix B.) A river pool, which is now filled with sediment, existed immediately upstream from the riffle. If the dam caused sediment deposition in the upper 2 miles of the reservoir, any other pools that existed would have quickly filled in with sediment and would also now be buried. However, the survey of the reservoir bottom found several pools that exist upstream from the public boat ramp. This further supports the belief that the dam does not cause permanent reservoir sedimentation upstream from the public boat ramp. Therefore, the sediment deposition caused by Savage Rapids Dam occurs in the ½-mile reach just upstream from the dam to the public boat ramp.

Coarse sediment (sand and gravel), which travels as bedload, has deposited in the ½-mile reach immediately upstream from the dam. Fine sediment (silt and clay) is easily suspended in the water column and carried past the dam. This permanent deposition of coarse sediment probably occurred within the first few years after the dam was built. All sediment entering the reservoir since that time (mostly during high flows) passes the dam. Visual observations confirm that even gravel-sized sediment is being transported past the dam (see figure 13 in Appendix B).

History of Mining Upstream From Savage Rapids Dam

Two mining areas lie partially within the Rogue River basin (see figure 1 in Appendix C). These include the Klamath Mountains and western Cascades mining areas. Three subareas within the Klamath Mountains mining area are upstream from Savage Rapids Dam. These are the Greenback-Tri-County area (which is located primarily in the Evans Creek Basin); the Gold Hill-Applegate-Waldo area that includes the Applegate River Basin downstream from the dam and numerous mines east of the town of Rogue River and the lower end of Bear Creek; and the Ashland area (which is located in the upper Bear Creek Basin) south of Medford (see Appendix C).

Most of the mines, other than placer mines, ceased working by 1940. Therefore, any materials discharged during active mining would be relatively deep in the reservoir sediment or not present at all. Dredging of placer deposits upstream from Savage Rapids Dam in the main stem of the river and on the lower reaches of many of its larger tributaries continued through the 1940s, and several continued into the 1950s and 1960s. There were also several large hydraulic operations in the basin (Brooks and Ramp, 1968).

Study Reach Evaluated

Sediment that is transported past the confluence with the Applegate River would be transported all the way to the Pacific Ocean, 95 miles downstream (see figure 1). Total stream power is an indicator of the river's ability to transport sediment (transport capacity). The total stream power is higher everywhere downstream from the Applegate River confluence (RM 95) than in the 12.5-mile reach from Savage Rapids Dam to the Applegate River confluence (see figure 4 in Appendix B). Any sediments that get transported past the Applegate River would keep moving through Hellgate Canyon. Just downstream from the mouth of Hellgate Canyon, the Rogue River becomes less steep, which would reduce sediment transport capacity. However, tributary flows from the Illinois River maintain the river's capacity to transport sediment at a relatively high level. Therefore, the reach of river studied in detail for sediment impacts following removal of the dam was from the upstream end of Savage Rapids Reservoir (near Evans Creek) to the confluence with the Applegate River.

Characteristics of the Study Reach

The Rogue River is a relatively steep, gravel- and cobble-bed river and consists of a series of pools, riffles, and rapids. In the 12.5-mile reach of river between the reservoir and the confluence with the Applegate River, the drop in water surface is just over 100 feet (see figure 2 in Appendix B). Eight of the pools in this reach are 10-20 feet deep (during low flow periods), and the remaining 10 pools are shallow (less than 10 feet deep).

Pools have greater depths and slower velocities than riffles, which have shallow depths, high velocities, and greater sediment transport capacity. During periods of low flows, water surface elevations through pools are relatively flat, velocities are low, and pools tend to slowly fill in with sediment (see figure 9 in Appendix B). During periods of high flows, such as the spring snowmelt or winter storms, the water surface slope through the pools increases, velocities increase, and sediment is eroded from the pools. Sediment is rapidly scoured from the channel bed of pools and transported down-stream. This natural process was observed at the U.S. Geological Survey (USGS) gauge cross section near Grants Pass (see figure 7 in Appendix B). During a winter storm in 1996-97, the channel bed at this section scoured out 6 feet and subsequently filled back in during low flow periods of the following year.

Types of Data Collected

A 2-foot contour map of Savage Rapids Reservoir was developed based on a sonar survey of the reservoir completed in July 1999 by Reclamation. (See attachments A and B in Appendix B.) The survey was performed from a raft equipped with a high-precision global positioning system and depth-sounding equipment. Using the same equipment, data were also collected along the river bottom downstream from the dam to the confluence with the Applegate River. These data were used to develop river cross sections for computer modeling purposes.

Additional data were collected to determine the volume, size, and chemical characteristics of sediments trapped behind Savage Rapids Dam (see figure 2 in Appendix A). Reclamation divers visually inspected the reservoir bottom for the presence of sediments in various parts of the reservoir. Concurrently, a drill rig was mounted on a barge to measure the thickness of reservoir sediments and collect samples for size and chemical analysis. These data, collected in the year-round reservoir pool, were combined with previous data collected by McLaren/Hart from adjacent bay deposits and along the margins of the reservoir.

Reservoir Sediment Volume

Reclamation surveyed 17 cross sections in Savage Rapids Reservoir in 1992 and estimated the reservoir sediment volume to be 516,000 cubic yards (yds³) (Blanton, 1992). This study was performed during the irrigation season (while the stoplogs were in place), and Blanton assumed that sediments had deposited along the entire 2.5-mile-long reservoir. Pre-dam topographic maps of the reservoir basin do not exist, and the 1992 study did not have the benefit of any measured sediment thicknesses to determine the elevation of the pre-dam river bed. Sediment sampling was limited to the collection of five samples along the rim of the reservoir. Therefore, the 1992 study estimated a pre-dam river bottom by assuming a constant slope through the entire reservoir (2.5 miles) based solely on the lowest

elevations among the 17 surveyed sections. In view of the general lack of available data and the assumptions made to estimate the pre-dam river thalweg (deepest point in the channel), the 1992 estimate was adequate for the appraisal-level study for which it was originally intended. However, based on the methods used to compute the sediment volume, it is apparent that several problems are inherent in this analysis. The method did not account for the pool and riffle complex that existed before the reservoir filling. Assuming a constant slope for the original river bottom overestimated sediment deposition in areas that are actually bedrock or riffles and underestimated areas which were actually pools that had filled with sediment. Because the reservoir has trapped sediments only in the ½-mile reach upstream from the dam, the 1992 volume estimate within the upper portion of the reservoir overestimated the actual sediment volume. The 1992 study underestimated the sediment volume in the lower reservoir (½-mile reach immediately upstream from the dam). Because of limited data and the resulting assumptions, the sediment volume estimate from the 1992 study was only accurate to the order of magnitude (hundreds of thousands of cubic yards) but not to the nearest hundred thousand cubic yards. Therefore, the volume estimate from the previous 1992 study is not comparable to the new volume estimate from this study because much more information was collected for this study.

Following the 1992 Reclamation study, McLaren/Hart collected data on the size and thickness of reservoir sediments (McLaren/Hart, 1998). These data were collected on exposed sediment bars along the margins of the reservoir during the nonirrigation season. The sediment volume within the sampled area was estimated to be 138,000 yds³. McLaren/Hart noted that this volume estimate was 2.5 times greater than Reclamation's previous estimate of 55,000 yds³ (Blanton, 1992) for the same ½-mile reach. The McLaren/Hart data were then extrapolated further upstream to include the same 2 ½-mile full-pool reservoir area as that used in the original Reclamation estimate. McLaren/Hart (1998) estimated that:

The total volume of sediment currently impounded. . .upstream of the Savage Rapids Dam is likely in excess of the 600,000 yds³, and perhaps as much as 1,000,000 yds³, based on the Reclamation estimate.

Because the McLaren/Hart estimate was based on an extrapolation of the 1992 Reclamation estimate, this study also did not account for the fact that sediments are not trapped upstream from the public boat ramp.

Based on the new reservoir sediment data and observations by Reclamation and the previous data collected by McLaren/Hart, the volume of reservoir sediments is estimated to be 200,000 yds³ (Appendix A). If this volume were placed on a football field, it would reach 100 feet high. This sediment volume is also roughly equivalent to 2 years of sediment load transported by the Rogue River at Grants Pass (Appendix B). Currently, this sediment load accounts for 70 percent of the transport capacity of the Rogue River at Grants Pass, assuming 30 percent of the sediment load is trapped upstream, in Lost Creek Reservoir.

Reservoir Sediment Sizes

Reservoir sediment consists mostly of sand and gravel (see figure 2 in Appendix A). Increases in turbidity are primarily caused by silt and clay-sized sediments that make up a very small portion (2 percent) of the reservoir sediment volume. Cobbles ranging in size from 3 to 5 inches in diameter and composing an estimated 5 to 20 percent by volume of the deposit were observed during geologic mapping of sediment exposures along the north shore of the reservoir.

Samples obtained from a finer-grained bar deposit on the south side of the reservoir show somewhat higher concentrations of fines (silt and clay) and average about 7.5 percent by weight with a maximum fines content of 20.7 percent noted in one sample (McLaren/Hart, 1998). This bar represents less than 10 percent of the total sediment volume stored behind Savage Rapids Dam. Downstream impacts from the higher fines content in the bar should be minimal because the south bar is located on an elevated bedrock shelf that forms the south rim of the reservoir. The bar is exposed at low reservoir elevations such as those anticipated during dam removal and erosion. Downstream transport of the south bar is not expected under low-flow conditions in the Rogue River. The south bar can be inundated and a portion of the existing sediment can be eroded and new sediment can be deposited during periods of high flow such as winter floods or spring runoff. But the high volume of riverflows needed to inundate the bar would tend to dilute the fines content and minimize any potential downstream impacts.

Contaminant Testing of Reservoir Sediment

A large amount of contamination was not expected in Savage Rapids Reservoir sediment because contaminants typically attach to finer-sized sediments, and these make up only 2 percent of the sediment behind the dam. Testing of reservoir sediment showed that there were no contaminants found with concentrations significantly higher than naturally occurring background levels (Appendix C). The chemical composition of reservoir sediment would not pose any hazard to water quality, fish and wildlife, or human uses if released from the reservoir.

Lower Columbia River screening levels for each chemical have been developed for use in the Pacific Northwest rivers. These screening levels provide a maximum concentration of chemical presence in river sediments that is considered acceptable. Sediments must be tested for chemicals-of-concern before they can be released if active sources of contamination are determined to be present (Corps et al., 1998). The testing is based on the Lower Columbia River Interagency Dredge Material Framework. The sediment behind Savage Rapids Dam was probably trapped within the first few years following the initial filling of the reservoir in 1921. Because a substantial amount of mining was done upstream from the dam during the early 1900s, reservoir sediment was tested for numerous chemicals-of-concern to determine if there was any risk in releasing the sediments.

Reservoir sediments along the channel margins in the ½ mile upstream from the dam were analyzed for chemicals-of-concern by McLaren/Hart (McLaren/Hart, 1998). The McLaren/Hart study found that levels of arsenic, cadmium, mercury, copper, lead, and zinc were all well below screening levels (compare tables 3 and 5 in Appendix C), except for the concentration of copper in one sample. Additional samples collected by Reclamation from deep in the reservoir pool were also tested for cadmium, arsenic, copper, lead, mercury, zinc, and iron. The data show that the chemicals-of-concern are well below screening levels and in the same range as natural background levels. While there is no screening level for iron, comparisons were made to levels downstream from a site where extensive mining has been done. These comparisons show that levels of iron in the reservoir sediment are well below even background levels.

Riverflows and Sediment Transport

River Hydraulics Computer Model

A river hydraulics model, HEC-RAS (Corps), was applied to the study reach (Brunner, 1997). This model can predict the following hydraulic parameters for any given discharge on the Rogue River:

- Water surface elevation
- Average velocity
- Water depth for any given discharge on the Rogue River

The data needed to create the model were channel geometry in the reservoir, channel geometry downstream from the dam to the confluence with the Applegate River, channel roughness (a flow resistance parameter), and water discharge. This model was calibrated to measured data to ensure its capability to accurately predict hydraulic parameters (see figure 8 in Appendix B). Model results were used to compare water surface elevation, average cross section velocity, and water depth for existing reservoir conditions and for river conditions after the dam is removed.

Sediment Transport Computer Model

A sediment transport model, HEC-6t (Thomas, 1993), was applied to the study reach. This model can predict not only hydraulic parameters but also:

- Erosion of reservoir sediments
- Sediment transport and deposition downstream
- Changes in the channel bed

In addition to the hydraulic data listed in the previous section, the sediment data required by the model include the natural sediment supply of the Rogue River upstream from the dam, the size and thickness of sediment present on the reservoir and river bottom, and a hydrograph depicting riverflows over a period of time. Model results were used to analyze the volume of sediment eroded from the reservoir, the rate of erosion, the rate of sediment transport downstream, and the temporary deposition along the river channel.

Riverflows Following Dam Removal

The exact riverflows (timing, magnitude, and duration) following dam removal are unknown, but the historic flows on the Rogue River can be used as an indicator of what can be expected to happen. Riverflows have been recorded since 1939 at a USGS gauging station near Grants Pass, Oregon (see figure 16 in Appendix B).

Flood peaks on the Rogue River typically occur from November to March, with most occurring in December and January (Appendix D). The largest mean daily flow recorded on the Rogue River prior to construction of Lost Creek Reservoir was 124,000 ft³/s (instantaneous peak of 152,000 ft³/s) in December 1964. Local records and photographs document the large portions of Rogue River, Oregon, that were inundated and the numerous homes that were destroyed. The magnitude of flood peaks has been significantly reduced following construction of Lost Creek Dam. The largest flood since Lost Creek Dam was constructed occurred during January 1997. The mean daily flow reached 69,000 ft³/s (instantaneous peak of 90,800 ft³/s) in January 1997.

Riverflows Used to Model Dam Removal

The magnitude of riverflows following dam removal will determine how fast the reservoir sediment is transported downstream. The higher the peak flows that occur, the quicker sediment will be transported to the ocean. Looking at the historic data since Lost Creek Dam was constructed (see figure 16 in Appendix B), a period of dry years (where very few winter storms occurred) started in the late 1980s. Before and after this period, several wet years were recorded during which numerous winter storms occurred. Two possible extremes were modeled: (1) dam removal followed by several dry years as occurred in the late 1980s and (2) dam removal followed by the wettest year that was recorded (1996-97 water year), followed by subsequent wet years (Appendix B). The modeling of both hydrologic extremes assumed two dam removal scenarios: (1) the dam would be removed in May (at the beginning of the summer low flows and the start of the irrigation season); and (2) the dam would be removed in November (after the irrigation season but at the start of the winter flood season).

Rate and Extent of Reservoir Sediment Erosion

Savage Rapids Reservoir is only two to three times wider than the natural river channel in the ½-mile reach just upstream from the dam. This means that nearly all the reservoir sediment trapped behind the dam would be eroded by the river rather than stranded as the water surface elevation of the river quickly decreases following dam removal. However, small sediment deposits may permanently remain along the margins of the reservoir.

An initial flushing of reservoir sediment would occur immediately following removal of the dam. This flushing occurs because, as the dam is removed, the river would seek a lower base level and begin incising through the sediment deposits behind the dam. This incision process and sediment flushing would continue until a stable slope is reached upstream from the dam site. This flushing would cause sediment concentrations¹ downstream from the dam site to significantly increase for a short duration of time immediately following dam removal (figure 4). After the initial flushing, successively higher flows would be required to erode more sediment from the reservoir deposits immediately upstream from the dam and again increase the sediment load to the downstream river channel. Sediment concentrations will be much higher than natural conditions during the first flood following dam removal. These high concentrations will tend to decrease toward natural levels with each subsequent flood. Between floods, sediment concentrations will be relatively low.

At the present time, no detailed plan has been formulated regarding the timing and sequence of dam removal. Various dam removal plans could be considered to evaluate the following sediment design parameters:

- The amount of sediment that could be sluiced through the radial gates before dam removal
- The season or month the dam removal would begin in accordance with in-river work periods
- The length of time over which the dam would be removed
- The length of dam section(s) that would be removed or permanently left in place²

For this study, it was assumed that the dam would be removed in a manner that would allow all reservoir sediments to begin eroding immediately following dam removal. Under this assumption, reservoir sediments would erode during the low-flow summer season when the transport capacity of the downstream river channel would be at its

¹ Sediment concentration refers to the mass of sediment transported by the river per unit volume of water. Sand-sized sediment is transported in suspension through riffles, rapids, and short pools where velocity and turbulence are high. Coarse-sized sediment (gravel and cobble) is transported as bedload.

² The plan in the PR/FES calls for full removal; pieces could be left on the abutments for historic interpretation and as a cost-saving measure.

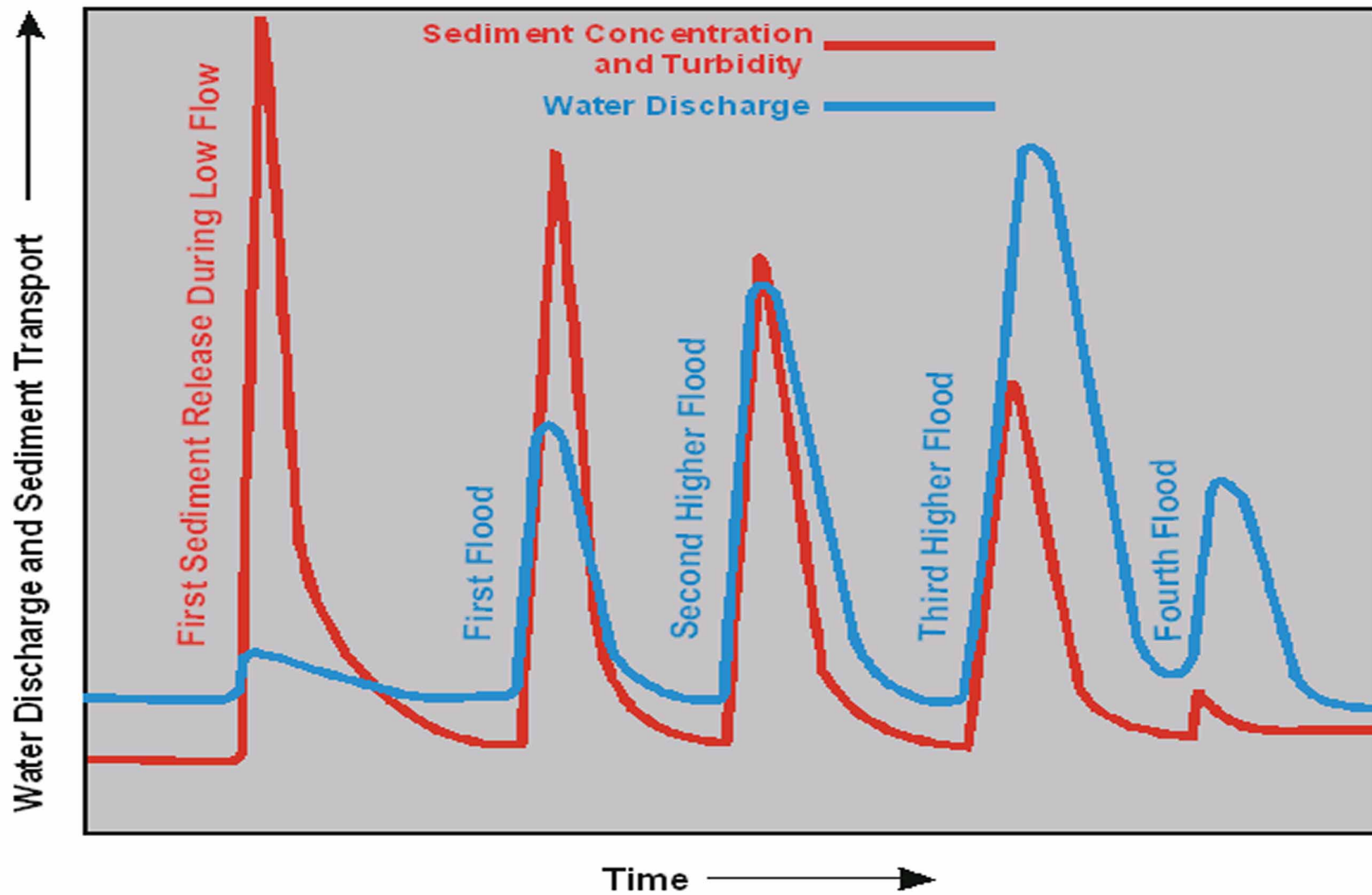


Figure 4.--Conceptual depiction of the relationship of water discharge and sediment transport in the downstream river channel following removal of a dam.

lowest. This would result in the maximum amount of deposition in the river channel downstream (especially pools and eddies). In contrast, if the reservoir sediment erosion could begin during the high-flow winter season, the amount of sediment deposition on the riverbed would be considerably less.

Model results show that if Savage Rapids Dam is removed, virtually all the sediment would be eroded from the reservoir (see figure 21 in Appendix B). Regardless of when the dam is removed and whether a series of dry or wet years follows removal (based on historical flows), about three-fourths of the reservoir sediment would be eroded from the area immediately upstream from Savage Rapids Dam within the first year.

Sediment Transport

The sediment that is eroded and flushed from the reservoir would be transported downstream. This sediment would temporarily deposit in areas of low velocity, such as pools and eddies (zones of recirculating flow). As sediment deposits along the bottom of pools and eddies (decreasing water depths), river velocities will increase until the velocities become so high that sediment is transported through the reach rather than deposited. Sediment deposition in pools and eddies would occur during low-flow periods, as it does now. Sediment would subsequently be scoured out and transported downstream during high-flow periods. All the sediment would be eroded and eventually reach the ocean.

The reservoir sediment would be transported past the Applegate River confluence (12.5 miles downstream from the dam) within a 1- to 10-year period. The length of time would depend on the frequency and magnitude of high-flow events following dam removal (see figure 22 in Appendix B). The 1-year period would require an extremely wet year with several high flows following dam removal, and the 10-year period would result if several dry years with very few or no high flow peaks followed dam removal. Maximum deposition levels would occur at various times following dam removal but not everywhere at once (see Appendix B, attachment F). Maximum deposition levels will range from 1 to 8 feet in river pools. No flooding as a result of the dam removal is predicted because all deposition would occur in river pools, and deposition in river pools would not cause an increase in water surface elevation. The time required for the sediment to reach the ocean depends on the frequency and magnitude of high-flow events. Most sediment transport would occur during floods. If flood magnitudes following dam removal are high and floods occur frequently, the reservoir sediment would reach the ocean within a few years. If the flood magnitudes are low or floods occur infrequently, the reservoir sediment would reach the ocean over a much longer period of time. Under either scenario, sediment concentration and transport rates would be relatively low and near natural levels between floods.

River Channel Following Dam Removal

Prior to the dam, a riffle existed at the dam site, and a pool was formed immediately upstream from the riffle (see figure 11 in Appendix B). These river features would be restored as the reservoir sediment that currently covers them is eroded and transported downstream. The water surface elevation in the ½-mile reach upstream from the dam would be lowered to near the pre-dam elevation if the dam were to be removed (see figure 23 in Appendix B) and would look much different from the way it looks today (Appendix B). However, upstream from the public boat ramp, the water surface elevation would look the same as it now looks during the nonirrigation season when the stoplogs are pulled out and the reservoir is lowered back to the permanent pool level.

The velocities through the dam site following dam removal were also estimated (see figure 24 in Appendix B). Three possible scenarios were evaluated to determine how removing all the dam versus only a portion of the dam would impact velocities (Appendix B). Looking at the cross section immediately downstream from the dam, most of the channel bottom to the left of bays 10 and 11 (where radial gates now exist) is composed of bedrock that would still exist after removing the dam. The results show that by removing bays 1 through 11, velocities will not exceed 10 feet per second at flows lower than 30,000 ft³/s. Existing velocities in Pierce Riffle, approximately 1 mile downstream from the dam, do not typically exceed 8 feet per second.

Sediment-Related Impacts to River Infrastructures as a Result of Dam Removal

In addition to the environmental impacts resulting from periods of high sediment concentration and from temporary deposition along the riverbed following dam removal, there are concerns about the impacts to specific structures located along the Rogue River downstream from the dam (Appendix B). Sediment-related impacts are addressed in this study for the structures listed below:

- Two pumping plants would be constructed (one on each side of the river) immediately downstream from the dam to enable the GPID to deliver water to its patrons through the irrigation canals during and after dam removal (see figure 25 in Appendix B).
- The existing Grants Pass city water treatment plant and intake structures are located about 5 miles downstream from the dam (see figure 26 in Appendix B).

Irrigation Pumping Plants.—If the dam were removed during the irrigation season and the reservoir sediment were allowed to erode downstream, sediment concentrations in the river channel (downstream from the dam) would be higher than normal. Because the new pumping plants would be located just downstream from the dam, there is concern that

sediment would deposit around the fish screens, at the pump intake, and in the intake channels between the river and pumping plants. If sand entered the pumping plant, it could damage the pumps through abrasion and potentially deposit along the irrigation canals. Fine sediment (silt and clay) would not damage the pumps or deposit in the canals. The best way to eliminate or minimize these potential impacts is to prevent coarse sediment from depositing around the fish screens or entering the pumping plants. This would be accomplished by locating the pumping plants along the river channel where the river velocities are relatively high and parallel to the fish screens. A low-elevation submerged training wall could be constructed in the channel to divert coarse sediments, which are transported as bed load, away from the fish screens. Temporary dredge pumps could also be employed to remove sediment from the fish screens and pumps, if necessary.

If the reservoir sediment is allowed to erode during the nonirrigation season, it would not impact the pumps or the irrigation canals because they would not be in operation. Some sediment may deposit around the fish screens or intake channel, but that sediment could be removed prior to the beginning of the next irrigation season.

Additional sediment would erode after the initial flushing of the reservoir sediment, but only during high-flow periods that would most likely occur during the nonirrigation season when the pumping plants would not be in operation. Riverflows and natural sediment loads would tend to be low during the irrigation season. In fact, very little coarse sediment would be transported during the low-flow (irrigation) season. Therefore, sediment impacts on the pumping plants would be minimal after the initial flushing of reservoir sediment has occurred following dam removal.

City Water Treatment Plant Intake Structures.—The concentrations of sand being transported by the river vary with depth and with location across the channel. Sand concentrations are much greater near the riverbed than near the water surface and tend to be greater along the outside of river bends than along the inside of bends. The intake structure for the city water treatment plant is located on the outside of a river bend and is relatively deep in the water. However, intake structures are normally designed to minimize (to the extent possible) the entrainment of coarse sediment. For computational purposes, the concentration of sand entering the treatment plant was assumed to be equal to the mean concentration in the river. Sand transport computations for the river indicate that riverflows have to exceed 21,000 ft³/s before gravel and sand can be transported by the river and sand concentrations are high enough to enter the treatment plant (Appendix B).

As mentioned above, sediment concentrations would be greatest if the reservoir sediments are first allowed to erode and be transported downstream during the irrigation season when riverflows tend to be low. As sediment is transported downstream by riverflows, some sediment would deposit in river pools and eddies (especially during low flows). This would diminish peak concentrations in the downstream direction. Because the Grants Pass city water treatment plant is located 5 miles downstream from the dam and because there

are several deep pools in this reach, sediment concentrations would be less at the treatment plant than at the irrigation pumping plants.

In general, getting suspended fine sediment (silt and clay) to settle out of water diverted from the river can sometimes be a difficult task for water treatment plants, especially if the concentrations are high. However, the percentage of fine sediment trapped behind Savage Rapids Dam is very low (2 percent)³, so it should not pose a significant problem for the city water treatment plant. Coarse sediment would rapidly settle at the treatment plant, but large settling volumes would require additional dredging and disposal. This would lead to increased labor costs. The reservoir sediment is predominantly sand (71 percent), and the volume of sand entering the treatment plant during the initial flushing of reservoir sediment would likely increase. In general, gravel-sized sediment would be too coarse to enter the treatment plant.

Water enters the Grants Pass Water Treatment Plant when river water is pumped directly into the intake structure, which is located on the right bank of the river (looking downstream). This water contains a certain concentration of sediment, all of which will eventually settle out in the plant as part of the treatment process. The amount of sand that would be deposited within the treatment plant from water pumped from the river following dam removal is difficult to predict with certainty. There are no measurements of sand transport by the Rogue River in the vicinity of the treatment plant intake structure. Also, the concentration of sand entering the treatment plant relative to the sand concentration in the river is not known. However, it is known that under existing conditions the amount of sand that gets pumped into the water treatment plant is generally between 5 to 15 cubic yards per year (G.A. Geer, City of Grants Pass, written communication, September 1, 2000), and nearly all of that volume enters during high-flow periods. Most of the sand in the existing riverbed is covered by gravel. Because it takes a fairly high flow to transport gravel, sand remains trapped at low flows, and the concentrations of sand transported by the river are near zero. However, when riverflows are high enough to transport the gravel on the surface of the riverbed, the sand transport rates dramatically increase and continue to increase exponentially with additional increases in riverflow.

The reservoir sediments would begin to erode during the removal of Savage Rapids Dam, even at low flows, in response to the higher river velocities through the former reservoir area. Sand and gravel-sized sediments would be transported downstream, but the volume would tend to diminish because sediment particles would temporarily deposit in river pools during periods of low flow. The river pools would progressively fill (in the downstream direction) to their sediment storage capacity. Consequently, a significant portion of the reservoir sediments would be temporarily stored in these river pools. The sand and gravel that is transported past the river pools would eventually reach the intake structure, and sand concentrations in the river would be temporarily high. The

³ The fines would go immediately and not be a long-term problem.

concentrations of sand in the river would reduce as the peak of the sand wave passed the intake structure during the low-flow period. Sand concentrations would remain low until riverflows were high enough to transport the sand that would be temporarily stored in the river pools. Sand concentrations would be temporarily very high during high riverflows.

Sediment model results for high-water years following dam removal indicate that 80 cubic yards of sand could deposit in the treatment plant within the first year following dam removal (see figure 27 in Appendix B). Peak rates of sand deposition could exceed 10 cubic yards per day for a few days and exceed 30 cubic yards over a 1-week period. Actual sand deposition volumes may be much less than the model predictions. Based on the assumed hydrology, sand deposition volumes would decrease to 20 cubic yards during the second year following dam removal. After that, deposition volumes would be nearly the same as under existing conditions. Sand deposition rates in the treatment plant would be less if dam removal were followed by low-water years, but the duration of impacts would be extended to several years.

High rates of sand deposition in the treatment plant could cause rapid wear on the river intake pumps and complicate the method of removing sand from the plant's three sedimentation basins. From the perspective of the city water treatment plant, it would be best to release sediment from the reservoir during the period November through March. This would allow for large portions of the sediment to be quickly transported past the treatment plant during high-flow periods. The water treatment plant is operated during these months at a slower pumping rate and for fewer hours per day (G.A. Geer, City of Grants Pass, written communication, September 1, 2000). The combination of a slower pumping rate and fewer hours of daily operation would lessen the impact of sand-sized sediment on the pumps and sedimentation basins.

There is concern that excessive deposition of coarse sediments in the vicinity of the water treatment plant could plug the intake structure. If this were to occur, a dredge would have to be employed to remove the coarse sediments. As a preventive measure, a submerged guide wall could be constructed in the channel that would force riverflows of high sediment concentration near the bed to flow past the intake structure. Water flowing near the river surface would have a lower sediment concentration than flow near the bed. This water would flow over the wall and tend to flush the area around the intake structure.

All the sediment-related impacts at the city water treatment plant can be handled but at additional cost. These additional operating costs are difficult to estimate without knowing the future hydrology and the details of the dam removal plan, but these costs could be measured through a monitoring program. The results of this study, relative to the potential impact of sediment transport and deposition, would have to be addressed in future analyses detailing when and how the dam would be removed. Mitigation of adverse impacts that could occur at the Grants Pass city water treatment plant, or anywhere else, could be explored as part of the final design process.

Sediment Monitoring Recommendations.—This study identifies the potential sediment impacts if Savage Rapids Dam is removed. If a dam removal plan is implemented, the following recommendations for data collection would provide necessary information for monitoring the actual sediment impacts during and following dam removal:

- Detailed mapping of the eight deep river pools between the dam and the Applegate River
- Sampling bed material of the eight deep river pools between the dam and the Applegate River
- Continued measuring of discharge at the USGS gauging station
- Measuring bed load and suspended-sediment concentrations at the USGS gauging station at Grants Pass
- Continuous measuring of turbidity during and after dam removal at three locations: (1) the highway bridge at the town of Rogue River, (2) immediately downstream from Savage Rapids Dam, and (3) the Grants Pass city water treatment plant river intake